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Technical Evaluation Report on the Guidance and Control Panel Symposium on Guidance and Control of Unmanned Air Vehicles

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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAIT DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.260

TECHNICAL EVALUATION REPORT

on the

GUIDANCE AND CONTROL PANEL SYMPOSIUM

on

GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES

by

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The Guidance and Control Panel 47th Symposium was held at the Letterman Army Institute of Research, Presidio of San Francisco, California, USA from 4 to 7 October 1988. The papers were compiled as Conference Proceedings CP.436 and CP.436(S).

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PREFACE

Unmanned Air Vehicles, which include RPVs and autonomous platforms have had a long history in the military field. Recent advances in guidance and control, in sensors and in data processing have led to an upsurge of interest in such systems within NATO. Several new RPVs are under development and there are numerous lessons that are being learned during the development and deployment of these systems.

This symposium intended to examine the state-of-the-art in the unmanned vehicle field covering both short range systems for tactical reconnaissance, target spotting and fire control and the long range systems carrying out surveillance tasks and autonomous platforms.

* * *

Les véhicules non-pilotés, qui comprennent les engins télépilotés (RPV) et les plateformes autonomes, sont connus de longue date dans le domaine militaire. Les progrès réalisés récemment en guidage et pilotage dans le domaine des capteurs et du traitement des données sont à l'origine d'un regain d'intérêt pour de tels systèmes au sein de l'OTAN. Plusieurs engins non-pilotés d'une nouvelle génération sont en cours de développement et nombre d'enseignements sont tirés au travers des réalisations et des déploiements de ces systèmes.

Le but de ce Symposium était de faire le point sur l'état des connaissances dans ce domaine. Ainsi, le programme englobait à la fois les systèmes à courte portée pour la reconnaissance tactique, le repérage d'objectif et la conduite du tir, et les systèmes à longue portée utilisés pour la surveillance et les plateformes autonomes.

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Le Panel tient à remercier les Délégués Nationaux des Etats Unis près l'AGARD de leur invitation à tenir cette réunion dans leur pays et de la mise à disposition de personnel et des installations nécessaires.

TECHNICAL EVALUATION REPORT on the
47TH GUIDANCE AND CONTROL PANEL TECHNICAL MEETING
Symposium on
GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES

1. INTRODUCTION

The 47th Guidance and Control Symposium on Guidance and Control of Unmanned Air Vehicles was held at the Letterman Institute of Research, Presidio of San Fransisco, San Fransisco, California, USA, from 4 to 7 October 1988. The Program Co-Chairmen for this meeting were Professor John T. Shepherd of the United Kingdom and Dr. John Niemela of the United States. The program, as presented at the symposium, is appended to this report. The complete compilation of papers will be published as AGARD Conference Proceedings.

Unmanned air vehicles, which include RPVs and autonomous platforms have a long history in the military field, characterized by long periods of neglect and indifference and short periods of intense interest. The motivation for addressing the guidance and control of unmanned aircraft at this time sprang mainly from two significant trends. First, the ever-increasing lethality and accuracy of modern weaponry is monotonically increasing the risk of carrying out manned missions on the battlefield. Thus there seems to be an expanding need for unmanned air vehicles to carry out an increasing diversity of missions, both offensive and defensive. Second, using the same technologies that are producing this increased battlefield lethality together with emerging concepts of artificial intelligence appears to offer the potential for unmanned systems with significantly enhanced capabilities. Consideration of these two emerging trends led the Guidance and Control Panel to the conclusion that now was a propitipous time to explore the situation through the vehicle of a symposium on the subject.

Accordingly, a symposium was organized on the subject of guidance and control of unmanned air vehicles with the stated objective of examining the state-of-the-art in the unmanned air vehicle field, covering both short range systems for tactical reconnaissance, target spotting, and fire control, and the long range systems carrying out surveillance tasks and autonomous platforms such as cruise missiles. Although the title of the symposium was limited to the guidance and control of unmanned vehicles, the scope of the symposium was in fact *much broader*. One session, for example, was planned to cover operational concepts, that is, if, and if so how, an unmanned system should be deployed in lieu of a manned system. Other sessions were planned to cover the design of the total unmanned vehicle system, optical sensor systems for unmanned vehicles, systems external to the vehicle needed for a total capability, and the evaluation and test of complete unmanned vehicle systems in addition to the core subject of guidance and control. The level of success achieved in developing meaningful discussion of these topics was uneven, as will be discussed in the body of this report.

This evaluation report includes consideration of the comments and recommendations which were received from the participants in the symposium on the form appended. Such comments are a great help to the evaluator and the efforts of those who took the time to make them are greatly appreciated.

2. DISCUSSION

2.1 Keynote Address

The keynote address was given by Rear Admiral William C. Bowes, Director of the Unmanned Aerial Vehicles Joint Project in the US Department of Defense. This project has only been in existence for a short time so that only planning activities have taken place to date. The most significant point is that the US DOD is taking a corporate approach to the exploitation of unmanned vehicle technology after years of false starts and inter-service rivalry. A broad spectrum of missions is being addressed including reconnaisance and surveillance, target acquisition, command and control, meteorological data collection, NBD detection, and disruption and deception missions. (One point brought out by Admiral Bowes with which this author **strongly** agrees is that many more uses for unmanned vehicle systems will suggest themselves to operational system users as they get their hands on the systems. It is unrealistic to expect that all possible system applications can be accurately assessed, or indeed even thought of, *by rear echelon* systems analysts.) Consideration of the need for systems to carry out these missions led to characterization of four types of systems. These are: close range (0-30 km), short range (150 km, 300 km desired), medium range (700 km), and endurance which is not characterized by range but rather by time of flight which for this system may be as long as 36 hours. Admiral Bowes finished his address by challenging the technical community to develop, produce and support viable unmanned vehicle systems and assuring the community of the support of his office in using such systems.

2.2 Session I: Operational Concepts

The first paper of this session, presented by Dr. Rumer of AGARD, was a summary of findings from several AGARD Aerospace Applications Studies on unmanned aircraft applications. The studies addressed the use of unmanned aircraft in the ground attack, beyond visual range air-to-air, and high altitude long endurance surveillance and target acquisition roles. Dr. Rumer s presentation was extremely comprehensive. He explained how AGARD studies are commissioned and accomplished as well as presenting the results of the specific studies being addressed. Point designs for vehicle, launch and recovery modes, command and control methodologies, on-board sensor requirements etc. were presented for each mission considered.

The other paper in the session, presented by Mr. Hansford of British Aerospace, was a report of studies done by his firm on the efficacy of unmanned fighter aircraft. (Mr Hansford s written paper is unfortunately not available, as of this writing. In addition, due to technical difficulties, his visual aids were not shown until his presentation was almost over. This makes assessment difficult. I will say, however, that his presentation under the circumstances was heroic.)

The conclusion of both papers was that properly designed unmanned aircraft systems for certain missions are feasible. One interesting point brought out by Mr. Hansford was that unmanned systems should have a life-cycle cost advantage over manned systems because machines don t have to practice.

2.3 Session II: Requirements and Systems

The first paper in this session grappled with the large issues first addressed in Session I. That is: What mission is an unmanned aircraft suited for and, having determined that, how should the unmanned system be implemented. The paper, presented by M. Martin of Command Systems Group, was an extremely thoughtful analysis of how to destroy an enemy s effectiveness as a fighting force by interdicting his critical C3 nodes using an integrated family of unmanned air vehicles. The paper forcefully highlighted the fact that the key to success is the ability to integrate a multi-payload multi-vehicle assemblage of equipment into an effective force for locating critical C3 nodes and marking them for destruction. This integration is so complex and the time for its implementation so short that many parts of the planning function will have to be done in software. The acceptance of this point by operational personnel is crucial in the battle for acceptance of unmanned vehicles. Mr. Martin pointed out three areas where this type of planning is required: assigning assets; route planning; and cueing software.

The next paper, presented by Mr. Denaro of the TAU Corp.dealt with the need for unmanned vehicles to provide target acquisition, not just target detection, on the modern battlefield. Once again, as in the previous paper, what this really means is that the computer will do the mission planning and the image data interpretation rather than the human. The need for this is undoubtedly valid and at some time the approach will undoubtedly be technically feasible. However, such methodologies will never be accepted by operational personnel unless means are developed to provide them assurance that the are "on top of" the situation and not at the mercy of a machine.

The next paper, presented by M. Chaillot of DRET SDCE, was a discussion of the various methods which could be used for unmanned vehicle guidance and on-board sensors that could be used for target location etc.

The final two papers of this session addressed the capabilities of existing systems. The first, presented by Mr. Dennis of GEC, was a quite thorough exposition of the capabilities of the Phoenix real-time battlefield surveillance system. The second, presented by Mr. Stroud of Lockheed discussed the Aquila unmanned air vehicle system, with emphasis on its target location capability. (Problems with the audio system unfortunately necessitated a lack of translation of these last two papers and cancellation of the discussion period planned for the end of the day.)

Once again aside from the technology presented in this session, the key issue seems to be that there is an ever-increasing need for automation to handle the ever-increasing amount of data being generated in ever-decreasing periods of time. The technology to permit this is well on the way but the question of how to keep the operational user informed about and comfortable with the situation may be receiving inadequate attention.

2.4 Session III: Vehicle Guidance and Control

This was the session addressing the core issue of the title of the symposium: guidance and control.

The first paper, presented by M. Boiffier of ENSAE, was an academic exposition of the synthesis of a lightweight low cost RPV and laws for control of the vehicle without recourse to a vertical gyro. Application of such a design would appear to be quite limited.

The next paper, presented by S. Sbuelz of Meteor, was a straightforward description of the autopilot of the Mirach 100 air-vehicle. The concept is somewhat unusual in that it uses OMEGA inputs in a differential mode for navigation.

The next paper, presented by M. Redoutey of Thomson-CSF, was a description of navigating RPV's using a radio-location system with a number of ground stations and a beacon on the RPV. It was stated that the system designers rely on short pulses, power management, and random-like times of transmission to avoid detection and hence jamming. It would seem that these ground transmitters could be one of those C3 nodes sought in paper 21.

The next paper, presented by H. Zinner of MBB, dealt with navigation by processing images from passive sensors. The authors frankly stated that this approach is presently not feasible but may be in the future. If made feasible from the computational point of view, the advantages of total passivity with connectivity to the real world are self-evident.

The final paper, presented by M. Guyvarch of Aerospatiale, dealt with navigation up-dating using map data obtained from radar. Again, the concept is to use processing power, including artificial intelligence, to obtain the necessary correlation, in lieu of human intervention.

There really was little inter-relation among the papers in this session. They ranged from straightforward descriptions of existing systems to discussions of concepts that are admittedly not yet feasible. Therefore, there are no further general comments.

2.5 Session IV: Optical Systems

Unfortunately, Session IV was not accomplished as the Program Committee had intended. Two of the planned five papers were, in fact, not presented. Interesting substitute papers were arranged at the eleventh hour. However, these papers were not particularly concerned with optical systems so that the planned focus of the session was regrettably lost.

The first paper, one of the substitutes, presented by Mr. Pendry of Marconi Defense Systems, concerned the operation of attack drones. One interesting point brought out is that drones at least offer **the potential for lower cost than missiles.** This is because it may be possible to relax environmental requirements for drones vis-a-vis those for missiles since drones can be stored in environmentally controlled containers rather than having to survive hung out on aircraft hard points. The system concept presented uses a beacon system for navigation and a broadband seeker for anti-radar attack. It was noted that the vehicle must be fairly stealthy since it must fly high to get into position for a steep dive top attack. A further valid point noted is that attack drones have several specific requirements. Thus, it is not realistic to expect that the attack role can be effectively filled by a "general purpose" drone.

The next paper, presented by Mr. Houston of Ferranti, was basically a history of Ferranti experience in the area of synthesis of sensor packages for target acquisition, detection, and designation. Past emphasis has been on television, other sensors will be examined in the future.

The next paper, the other substitute, was presented by Mr. Fry of British Aerospace. It concerned a low-cost concept for the navigation of RPVs loitering out of line of sight of any ground control station. The concept is for the loitering RPV to interrogate previously emplaced small low-cost beacons. With proper processing, precise knowledge of the beacon locations is not required.

The two remaining papers in this session were both from Lockheed and both addressed developments based on the Aquila system which has completed development.

The first, presented by Mr. Amick addressed an attempt to reduce system cost by introducing standardization into the development of sensor platforms. The goal of the program discussed was to design a common platform for all sensors, together with common reprogrammable controls and Ground Support Equipment, rather than the unique special purpose system built around each sensor, as is the case today. The result of the program is the LOCKHEED ADAPTIVE MODULAR PAYLOAD (LAMPS). It would seem that this type of process must be undertaken if the cost-reducing benefits of standardization are ever to be realized.

The final paper of the session presented by Mr. Thompson was an exceptionally clear presentation of automated search algorithms for target acquisition developed for and validated in the U. S. Army Aquila Remotely Piloted Vehicle system.

Because of the fragmented nature of this session, general comments are difficult to make. However, there is one point that was made implicitly that deserves being noted explicitly. The point is that the drive for standardization in an attempt to reduce cost is causing major changes in the way firms in the aerospace industry interact. This applies to the development of standard data busses, standard electrical and mechanical interfaces, etc. as well as to the sort of effort discussed

here.) Traditionally, suppliers have designed entire subsystems, such as a sensor package, and delivered them to airframe manufacturers for integration with other subsystems. However, suppliers cannot develop standard subsystems when they don't know, and will never know, because of proprietary considerations, the peculiar requirements of their competitors' equipment. Thus, only the prime contractor can develop standard subsystems. This trend is changing the traditional roles of the various firms in the aerospace community. The ultimate result of these developments is by no means clear but there is no question that the changes taking place are major and the resultant effect on the make-up of both airframe companies and their suppliers will be profound.

2.6 Session V: Systems External to the Vehicle

The first paper of this session, presented by M Olivier of ONERA, was a straight-forward comprehensive overview of ways to help maintain the data link between RPV and ground in the prescence of various impediments to doing so.

The second paper, presented by H Hornfeld of MBB, dealt with using a digital map display as an aid in planning, control, and target position determination. The system presented is called Intelligent Graphics Overlay System, IGOS. The paper went into quite a bit of detail on the design of the various versions of the system. Unfortunately, however, it did not address in very much depth why the system characteristics are what they are. That is, what the underlying perceived needs were that led to the design decisions made. This is a very exciting area of technology. The use of digitally generated maps for pre, during, and post-mission functions is continually increasing as more and more people become aware of the tremendous potential such systems offer.

The next paper was presented by Dr. Dannenberg of MERIT Technology. It addressed Dr. Dannenberg's perception of the impact of direction given by the US Congress in 1988 on RPV operations. It is Dr. Dannenberg's thesis that this direction mandated centralized control of the launch, control, and recovery of RPVs. Mr. Dannenberg then presented a most interesting concept for accomplishment of the mission planning function, given that centralized control was, in fact, mandated. This paper produced by far the strongest emotional response by the attendees of any in the entire symposium. Several delegates expressed the strongly held opinion that the bureaucracy created by attempting to centrally control RPV operations would render the whole concept so untimely as to be useless. This controversy is just beginning.

The next paper (which is unfortunately not available at this writing), presented by Mr. McGinn of GEC, concerned using imagery from the SPOT satellite as a data base for scene matching. The conclusion of the work accomplished to date is that the imagery is adequate for mid-course navigation of a stand-off missile.

The final paper of this session, presented by Mr. Sauvain of Lockheed, was a thoughtful assessment of how to determine the proper level of automation of tasks in a given system and further, how to allocate functions between hardware and software. A key element in Lockheed's approach to addressing this problem is to quickly prototype man-machine interfaces and get operational people in to assess their characteristics.

This session evolved into an assessment of global issues. The discussion of what degree of centralization in the operation of RPVs is just one example. Full consideration of this question has to include how organizations are partitioned, perhaps up to and including NATO. This is obviously a most complex issue but one that must be addressed continuously. Again, the questions of which functions get automated, which in hardware and which in software are fundamental to the design process and methodologies for making these decisions are of the utmost importance.

2.7 Session VI: Evaluation and Test

The first paper in this session, presented by Mr. Sevtang of British Aerospace, addressed an unmanned bomber primarily designed for air-to-ground missions, as opposed to the system discussed in paper 12 which addressed primarily the air-to-air role. Based on the work done to-date, the author feels that an RPV with a data link, a man-in-the-loop, etc. is too complex for this mission. He thus addresses multi-role drones or autonomous aircraft acting in a role similar to that of a manned aircraft. The selected concept is for the Unmanned Aircraft (UMA's) to be launched from manned aircraft and autonomously penetrate, search, detect, and attack. Studies have led to the choice of a millimeter wave radar as the target sensor. The ranging capability of the radar permits setting up multiple target passes. One sensor is felt to be adequate since groups of targets, rather than single targets, are sought.

The final paper of this session, and indeed, of the symposium, was presented by Mr. Ferguson of Lockheed. A very clear description of the Aquila system was

presented. The subject of the paper was the test program carried out on the Aquila navigation and guidance system, including a discussion of actual test data, a commodity which seems to be growing ever more rare.

The UMA bomber paper again raised the concern about identification of Friend or Foe (IFF) which always arises when autonomy and lethality are linked. The IFF problem is addressed solely by relying on the validity of reports as to where friendly forces are located. This is a very troublesome problem, the difficulty of which escalates, as the degree of lethal system autonomy grows. The fact that there were only two papers in this session brings home the fact that real test data on real systems is exceedingly scarce. In fact, the first paper, although backed by extensive experimental work, concerned a postulated, rather than an actual, system. One wonders if there is not too much emphasis placed on studying and assessing what system to build instead of getting on with building a strawman system and testing it to guide the course of further efforts.

2.8 <u>Roundtable Discussion</u>

Professor Shepherd was the Moderator for this discussion. The Roundtable was manned by Dr. Dannenberg of the US, Mr. Jones of the UK, H. Rumer of AGARD (Ge), and M. Materel (FR).

The discussion was started by asking the panelists their views as to business prospects for unmanned air vehicles. Comments were as follows: Fr: A definite need in the Army, the situation in the Air Force and Navy is more complex. US: Competition is underway on a mid-range vehicle. Competition is expected to start early in 1989 for a short range vehicle. Close range and endurance programs are expected in 1990. UK: Army-in service, RN-sitting on the fence, NATO needs to target for MLRS. Ge: Using CL 289, anti-armor and anti-radar in project definition.

The second question posed was "How quickly will we get autonomous systems". **There was no clear answer to this question.** Comments were: Operational types have to be convinced; manned aircraft are becoming unaffordable; Maybe never, because of the positive Identification Friend or Foe problem.

A discussion ensued on the helicopter threat to unmanned aircraft. The Aquila people felt that the threat was not great to a small properly configured aircraft. In addition, a helicopter costs more so a one-for-one would be cost effective.

The next topic of discussion was the feasibility of developing an unmanned fighter aircraft. The consensus seemed to be that technologically the concept was perfectly feasible. Courage and the political will to succeed were the most important things needed.

Finally, as is so often the case, everyone agreed that C3 is an extremely important problem, but nobody offered any suggestions as to what to do about it.

3. CONCLUSIONS

The conclusions presented here are solely those of the author, based on the written papers, presentations, and discussions of the symposium and on the forms handed in by the symposium delegates.

3.1 There seems to be a general consensus in the technical community that the technology is in hand for a vast increase in the use of unmanned air vehicles. Accomplishment of missions ranging from reconnaissance and surveillance, through logistic re-supply to areas under attack, to autonomous attack fighter and bomber aircraft, seem to be becoming technologically feasible. The increasing lethality of the battlefield coupled with the increasing availability of sophisticated automation technology seem to make this increase in unmanned air vehicle exploitation inevitable. However, this expansion of use may be limited to non-lethal missions due to the lack of capability for autonomous <u>positive</u> identification of friend or foe.

3.2 The US Department of Defense has signalled a significant increase in the level of its interest in unmanned air vehicles by creating the Unmanned Aerial Vehicles Joint Project. However, the scope of this project is limited to non-lethal vehicles so that only part of the problem is being addressed by the joint project office.

3.3 The ever-decreasing time available for decision making, together with the ever-increasing amount of data to be considered, mandates the use of decision aids, task automation, etc. The technology for this type of automated system is increasingly available. However, the key to success is not the technology to do the job, but rather development of means to assure operational decision makers that they are "on top of" the situation and not at the mercy of a machine.

3.4 The drive for standardization as a cost reducer is altering the traditional relationships of prime airframe manufacturers and sub-system suppliers. More and more sub-system work is being carried out by the primes themselves in the interests of standardization. This trend, if not carefully managed, could lead to an atmosphere which stifles initiative and diversity. Standardization must be applied intelligently and cooperatively, across the industry, if an atmosphere supportive of innovation is to be maintained. Achieving this important goal is a challenging task.

3.5 The degree of centralization of control of RPVs is a major factor in the ultimate success or failure of an RPV system. The underlying question here, as it so often is, is how best to accomplish the functions of command and control. This is an extremely complicated problem with obvious political as well as technical dimensions. The issue must be addressed and it must be addressed in a broad forum (ie. across NATO) if conclusions reached are to receive general acceptance.

4. RECOMMENDATIONS

4.1 In view of the fact that the community seems poised for a great expansion in the use of unmanned air vehicles, it is recommended that the panel re-visit this topic in no more than three years, possibly sooner.

4.2 Separate and apart from the subject of technology for unmanned air vehicles, the question of the degree of centralization of their operational control demands early careful examination. An AGARD Aerospace Applications Study on this topic might be appropriate.

4.3 The problem of operational acceptance of automation, decision aids, etc., etc. must be addressed by the technical community. This must be done in a way that demonstrates to operational personnel that the technical community realizes that their concerns are legitimate. Only with a major effort on this question will this type of system gain acceptance.

APPENDIX I

FINAL PROGRAM

GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES
San Francisco, California, USA, 4-7 October 1989

Opening ceremony:

Keynote Address by Rear Admiral William C. Bowes,
Director of the UAV Joint Project Office,
Washington, DC, USA

SESSION I: OPERATIONAL CONCEPTS
CHAIRMAN: Dr. J. Niemela (US)

11: Unmanned aircraft applications: A summary of findings from AGARD Aerospace Applications Studies
K. RUMER — AGARD-MCS Neuilly s/S, FR.

12: Operational requirements for unmanned combat aircraft
C. H. HANSFORD — British Aerospace PLC
Kingston-on-Thames, Surrey, UK.

SESSION II: REQUIREMENTS AND SYSTEMS
CHAIRMAN: Dr. H. Winter (GE)

21: Operational requirements for multipayload UAV missions in support of enemy critical C3 node interdiction objectives
M. I. MARTIN — Command Systems Group, Inc
Torrance, CA, US.

22: Target acquisition in the UAV environment
R. P. DENARO, P. A. CIGANER — TAU Corporation
R. M. KALAFUS — Los Gatos, CA, US.

23: Comparaison des techniques d'autoguidage et de téléguidage
Comparison between self and remote guidance for unmanned aircraft
B. CHAILLOT — DRET/SDCE, Paris, FR.

24: The Phoenix real time battlefield surveillance system
R. W. DENNIS, P. T. JONES — GEC Avionics Limited,
Rochester, Kent, UK.

25: Accurate determination of target locations using unmanned air vehicles
D. W. STROUD — Lockheed Missiles & Space Co.
Austin, TX, US.

SESSION III: VEHICLE GUIDANCE AND CONTROL
CHAIRMAN: J. B. SENNEVILLE (FR)

31: Lois de commande pour avions non pilotés, et minimisation du nombre de capteurs
Synthesis of control law, on a RPV, in order to minimize the number of sensors.
J. L. BOIFFIER — ENSAE, Toulouse, FR.

32: Mirach 100 flight control system
A. SBUELZ — Meteor CAE SpA, Ronchi dei Legionari (GO), IT.

33: Suivi de la navigation de RPV's a l'aide du système de radiolocalisation Trident IV
Navigation of reconnaissance RPV's with Trident IV radiolocation system
M. REDOUTEY, B. DUMAS — Thomson-CSF, Paris, FR.

34: Navigation of autonomous air vehicles by passive imaging sensors
H. ZINNER, R. SCHMIDT — MBB GmbH, Muenchen, GE.
D. WOLF

35: Recalage de navigation par cartographie radar: optimisation et validation par outil de simulation
Navigation up-date using radar mapping: assessment and optimisation simulation tool
J. F. GUYVARCH — Aérospatiale. Verrières le Buisson. FR.

SESSION IV: OPTICAL SYSTEMS
CHAIRMAN: C. BRIGHT (CA)

41: Guidance and control of attack drones
R. PENDRY (presentor) — Marconi Defence Systems
M. WINSTONE (author) — UK.

42: Electro-optic sensors for surveillance and target acquisition
A. HOUSTON, J. JACK — Ferranti Defence Systems, Ltd. E/O Dept. Edinburgh, UK.

43: Beacon Navigation
C. FRY — British Aerospace UK.

44: Unmanned air vehicle payloads and sensors
G. AMICK — Lockheed Missiles & Space Co. Austin. TX. US.

45. Automated search techniques applied to optical payloads in unmanned air vehicles
J. THOMPSON, R. MOODY — Lockheed Missiles & Space Co. Austin. TX. US.

SESSION V: SYSTEMS EXTERNAL TO THE VEHICLE
CHAIRMAN: S. LEEK (UK)

51: Protection des liaisons de donnees pour systemes RPVs face aux contre-mesures électroniques: Etude comparative de différents procédés de contre-mesures
RPVs data links protection against electronic counter-measures (ECM): A comparative study of different types of ECCM techniques
C. OLIVIER, M. STARON — Direction Etudes de Synthèse ONERA, Chatillon. FR.

52: Digital map display for flight planning, control, and target position determination
W. HORNFELD — MBB GMBH Marine und Sondertechnik. Bremen. GE.

53: An intelligent RPV mission planner
K. DANNENBERG, G. BARNEY, C. KIRKLEN — Merit Technology, Inc. Plano, TX, US.

54: Assessment of SPOT satellite imagery as a database for scene matching
M. HOWE (presentor) — E/O Advanced Systems Division
W. McGINN (author) — GEC Sensors Ltd., Basildon, UK.

55: Distribution of hardware and software elements in unmanned air vehicle systems
L. SAUVAIN — Lockheed Missiles & Space Co. Austin, TX, US.

SESSION VI: EVALUATION AND TEST
CHAIRMAN: PROFESSOR J. T. SHEPHERD (UK)

61: Technology and evaluation of unmanned air vehicles
G. SEYFANG — British Aerospace MAD, Warton Aerodrome, Preston, UK.

62: Navigation and guidance testing of the Lockheed Aquila remotely piloted vehicle
S. FERGUSON — Lockheed Missiles & space Co., Austin, TX, US.

ROUNDTABLE DISCUSSION: Professor J. T. Shepherd, Moderator

APPENDIX 2

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT
GUIDANCE AND CONTROL PANEL
7, RUE ANCELLE, 92200 NEUILLY-SUR-SEINE, FRANCE
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Guidance and Control Panel 47th Symposium
GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES
October 1988, San Francisco, CA, USA

QUESTIONNAIRE FOR ALL PARTICIPANTS

Considerable time and effort was expanded by the Programme Committee, the authors and the organisers hosting this symposium. As a result, the Programme Committee Chairman has commissioned an expert to draft a Technical Evaluation Report. To aid him in preparing a timely, meaningful report, and since we have assembled here leading technical experts in the field, we solicit any feedback or comments you may desire to submit. These may be handwritten notes, and anonymous. If you have any questions, please contact the AGARD Staff, the Programme or the Panel Chairman.

My name and address are:

1: In your view did the papers presented meet the published objectives of the Meeting ?

- [ ] Most
- [ ] About half
- [ ] Very few

2: Were the topics selected for presentation of interest to you ?

- [ ] Most
- [ ] About half
- [ ] Very few

3: Was the general level of the papers:

- [ ] Too deep
- [ ] Satisfactory
- [ ] Too superficial

4: Were the speakers effective in presenting their topics ?

- [ ] Most
- [ ] About half
- [ ] Very few

5: Time was allowed for discussion after each presentation, and at the end of the Meeting. Was this:

- [ ] Too little
- [ ] About right
- [ ] Too much

6: Was the meeting effectively organised (location, joining instructions, duration, audio visual equipment, refreshments, etc).

- [ ] Yes
- [ ] No - please amplify

7: Did language cause a problem ?

- [ ] Yes - please amplify
- [ ] No

8: Please add any other comments you may have:

9: Overall, what was your assessment of the meeting ?

Excellent	Very good	Good	Satisfactory	Poor
[ ]	[ ]	[ ]	[ ]	[ ]

10: Please add here any suggestions you have for follow-up activity in this field, or for AGARD Lecture Series, Courses, Symposia etc. in other fields.

Thank you for completing this questionnaire. Please hand it in to the registration desk, or to any of the AGARD Staff.

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Infrared guidance	Unmanned vehicles

14. Abstract

Evaluation Report on the Guidance and Control Panel 47th Symposium held at the Letterman Army Institute of Research, Presidio of San Francisco, California, USA from 4th to 7th October 1988.

Papers were presented covering the following headings: Operational concepts, Requirements and systems, Vehicle guidance and control, Optical systems, Systems external to the vehicle, Evaluation and test.

AGARD Conference Proceeding No.260 Advisory Group for Aerospace Research and Development, NATO TECHNICAL EVALUATION REPORT ON THE 47th GCP SYMPOSIUM, GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES by Charles T.Elliott 16 pages Evaluation Report on the Guidance and Control Panel 47th Symposium held at the Letterman Army Institute of Research, Presidio of San Francisco, California, USA from 4th to 7th October 1988. Papers were presented covering the following headings: Operational concepts, Requirements and systems, P.T.O	AGARD-AR-260 Dilemma cost/efficiency Inertial guidance Infrared guidance RPVs Target acquisition and identification Target reconnaissance Unmanned vehicles	AGARD Conference Proceeding No.260 Advisory Group for Aerospace Research and Development, NATO TECHNICAL EVALUATION REPORT ON THE 47th GCP SYMPOSIUM, GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES by Charles T.Elliott 16 pages Evaluation Report on the Guidance and Control Panel 47th Symposium held at the Letterman Army Institute of Research, Presidio of San Francisco, California, USA from 4th to 7th October 1988. Papers were presented covering the following headings: Operational concepts, Requirements and systems, P.T.O	AGARD-AR-260 Dilemma cost/efficiency Inertial guidance Infrared guidance RPVs Target acquisition and identification Target reconnaissance Unmanned vehicles
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